PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Anamorphotic Lens Systems

We, KODAK LIMITED, a Company organised under the Laws of Great Britain, of Kodak House, Kingsway, London, W.C.2, (Assignees of RUDOLPH KINGSLAKE and KARL TOLLE) hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to anamorphotic lens systems.

Anamorphotic lens systems comprise cylindrical lens components which produce different degrees of magnification in different directions in the plane of the image. It is customary to refer to the axial plane of an anamorphotic lens system in which the magnification differs most from unity as the active plane and the axial plane perpendicular to the active plane is referred to as the neutral plane. The ratio of the magnification in the active plane to that in the neutral plane is called the stretch magnification. An anamorphotic system is combined or may be attached to an optical system consisting of spherical lens components to produce an image of the required overall linear magnification and stretch magnification. When the anamorphotic system is afocal, it is customary to locate it in a part of the optical system where the light is nearly collimated or is only slightly convergent.

According to the present invention there is provided an anamorphotic lens system for use with a spherical lens system so as to receive therefrom a convergent bundle of image forming rays and to form an anamorphosed image in a plane near the image plane of the spherical lens system, comprising two components, axially aligned with the spherical lens system, the front component, next to the spherical lens system, consisting of two simple cylindrical lenses and having a positive power in the active plane and substantially zero power in the neutral plane and the second component consisting of a positive cylindrical doublet and a simple biconcave cylindrical lens and having a negative power in the active plane numerically greater than the power of the front component and substantially zero power in the neutral plane, and a simple meniscus lens element having negative power in the neutral plane and located between the second component and the plane of the anamorphosed image with its concave surface facing the front of the lens system.

In the accompanying drawings:—

Fig. 1 is a diagrammatic axial section in the active plane of an anamorphotic system according to the invention;

Fig. 2 is a diagrammatic axial section in the neutral plane of the system shown in Fig. 1; and

Fig. 3 shows diagrammatically another form of the invention, the upper half being a section in the active plane and the lower half being a section in the neutral plane.

In Figs. 1 and 2 an anamorphotic optical system is shown by way of example which comprises a front member of positive power in the active plane and made up of cylindrical lenses 1 and 2, a middle member of negative power in the active plane made up of a positive doublet composed of cylindrical lens elements 3, 4, and a simple cylindrical negative lens 5, and a meniscus rear member made up of a simple spherical lens 6 having negative power and a cylindrical simple lens 7 having positive power in the neutral plane.

In Fig. 1 a fan of rays represented by rays 11^1, 11 and 11^{11} is shown emerging from the rear surface 10 of the standard spherical optical systems, indicated only in part, and converging towards an image point 12 on the image plane 13 of the standard optical system as shown by broken lines. The rays are intercepted by the anamorphotic system, however, and redirected to the image point 14 in the image plane 15 a short distance behind the original image plane 13. In this example, the magnification is 2 in the active plane shown in Fig. 1, the effect on rays laying in this plane being the same as if lenses 1 to 6 all had spherical surfaces and lens 7 were a plane-parallel plate.

[*Price 3s. 6d.*]

Price 4s 6d

Fig. 2 shows the same system in the neutral plane. In this plane, a fan of rays 21^1, 21, 21^{11}, corresponding to 11^1, 11, 11^{11}, is shown emerging from the rear surface 10 of the spherical lens system and converging towards the image point 22 in the original image plane 13 as shown by broken lines. These rays, however, are intercepted by the anamorphotic system and redirected towards the image point 24 in the image plane 15. The major effect on rays in this plane is as if all the lens elements were plane parallel plates. Elements 6 and 7 act in this plane as spherical surfaces, but, because of the proximity to the focal plane, this is a minor effect. Thus, the rays in this plane are merely displaced by an amount such that the image point 24 is displaced from the image plane in a direction substantially parallel to the axis by a distance which is the sum of all the individual image displacements. The individual displacement by each lens acting as a plane parallel plate is t (n-1)/n, as given in Edser "Light for Students," page 55. This, of course, is only a rough value as regards elements 6 and 7, but it shows why the image plane tends inexorably to be displaced towards the rear, since in practice lenses cannot be made up with zero thickness.

We find it advantageous to compute the focal position in the neutral plane first and adjust some lens parameter such as the power of the front component or, for small changes, an airspace in the front component to make the focal position in the active plane coincide therewith.

The four distinct astigmatic curvatures of field, previously mentioned, are identified as follows: In Fig. 1 the tangential or primary image point is at the focal point of the fan of rays 11^1, 11, 11^{11}. Precisely speaking it is the focal point of the rays infinitely close to ray 11. The secondary or sagittal image point is at the focus of the rays in front and behind the diagram which coincide with ray 11 when projected onto the plane of the diagram. These image points define the two curvatures in the active plane. In Fig. 2, similarly, the primary image point is at the focus of the fan of rays 21^1, 21, 21^{11}, and the secondary image point is at the focus of the fan of rays which coincide with ray 21 when projected onto the plane of the diagram. These two image points define the two curvatures in the neutral plane.

Restricting our consideration now to the main body of the anamorphotic system (elements 1 to 5) the cylindrical axes are all parallel and the primary curvature in the active plane is computed and controlled in the same way as primary curvature in an ordinary system of spherical lenses. The fan of rays in the neutral plane, however, is not subject to any surface powers in this part of the system and so has previously been thought to have negligible image curvature. We have discovered, however, that this secondary curvature is inherently inward.

Considering only the main body of the anamorphoser, the primary curvature in the neutral plane (Fig. 2) is computed as if lenses 1 to 5 were plane parallel plates. By standard computing formulae it is known that this leads to a backward curving field. The secondary curvature combines the effect of plane parallel plates in bending ray 21 and the effect of the surface curvatures on the convergence of the tangential fan of rays. This curvature, accordingly, does not follow the same rules as any known aberration of systems of spherical lenses, but it seems similar to the secondary curvature thereof in that it changes roughly one-third as fast as the primary curvature in the active plane when a cylindrical surface curvature is varied.

Whatever the true theory of these curvatures may be, we have discovered that an anamorphosing system of this type cannot be corrected without introducing a lens having negative power in the neutral plane to contribute backward secondary field curvature to balance the inherently inward curving secondary field in the active plane.

In the example shown in Figs. 1 and 2, we have introduced a negative field flattening component in the form of a negative meniscus lens 6 having spherical surfaces and differing negative powers in the active and the neutral planes and, because unit magnification was required in the neutral plane, we added a plano-convex cylindrical lens 7 having positive power in the neutral plane of the system. Because of the shape of this lens 7 being plano-convex rather than meniscus, it only partially counteracts the field-flattening effect of the negative lens 6 even though its power in this plane is greater than that of the lens 6.

The main part of the system, of course, has to be re-designed to readjust the primary curvature in the active plane, the coma, the spherical aberration and the axial astigmatism.

The following table gives constructional data for this system as finally designed, on a scale such that the total length from the vertex of the front surface to the plane of the anamorphised image is 100 mm.

Stretch Magnification = 2x

Lens	N	V	Radii	Thicknesses
1	1.611	58.8	R'_1 = +25.96 mm	t_1 = 5.76 mm
			R'_2 = +61.75	s_1 = 0.80
2	1.605	43.6	R'_3 = +61.75	t_2 = 3.01
			R'_4 = +21.64	s_2 = 40.90
3	1.517	64.5	R'_5 = −30.78	t_3 = 2.78
4	1.649	33.8	R'_6 = +36.07	t_4 = 8.32
			R'_7 = −53.51	s_3 = 1.11
5	1.517	64.5	R'_8 = −53.51	t_5 = 2.38
			R'_9 = +36.07	s_4 = 19.63
6	1.517	64.5	R_{10} = −34.38	t_6 = 2.14
			R_{11} = −98.06	s_5 = 0.40
7	1.517	64.5	R_{12} = ∞	t_7 = 3.26
			R''_{13} = −37.43	L′ = 9.51

In this table the lens elements are numbered from front to rear in the first column and the respective refractive indices N for the D line of the spectrum and the dispersive indices V are given in the second and third columns. The front is taken as the end of the anamorphosing system which faces the standard system and the rear as the end nearest the focal plane. The radii of curvature R of the optical surfaces, the thicknesses of the lens elements and the spaces s between elements, each numbered by subscripts from front to rear, are given in the fourth and fifth columns, as is also the distance L^1 from the last optical surface to the focal plane. The radii of curvature of cylindrical surfaces are designed as R^1 if curved in the active plane and as R^{11} if curved in the neutral plane. Also, as customary, the + and − values of the radii denote surfaces respectively convex and concave to the front.

The lenses 6 and 7, have a field flattening effect of about 0.4 mm each on the primary and the secondary curvature in the active plane (Fig. 1) along a ray intersecting the final image plane at about 15 mm. from the axis.

Fig. 3 shows diagrammatically another form of the invention in which the field flattening toric lens 47 corresponds to lens 6 of Figs. 1 and 2 and in which the positive spherical lens 43 corresponding to lens 7 of Figs. 1 and 2 is nearer the front of the system. As mentioned before, the upper half of the diagram is half of a section in the active plane, and the lower half is half of a section in the neutral plane, corresponding to Fig. 1 and to Fig. 2 respectively.

The positive lens 43 is required near the front of the system to provide unit magnification in the neutral plane. In case unit magnification in the neutral plane is not required the lens 7 or 43 with positive power in the neutral plane may be omitted altogether. This lens 7 or 43 with positive power in the neutral plane also gives an added variable with which to control the inherent backward curvature of the primary field in the neutral plane.

This example is made up of cylindrical lenses 41 and 42 corresponding in function to lenses 1 and 2 of Figs. 1 and 2, the positive spherical lens 43 whose position and power provide two variables for simultaneously controlling the magnification in the neutral plane and the displacement of the focal plane, followed by a cylindrical doublet 44, 45 and a simple cylindrical lens 46 corresponding to 3, 4 and 5, and finally a toric lens 47 corresponding to lens 6. As shown, the power of the lens 47 in the active plane of the system is zero, and that in the neutral plane is negative for flattening the secondary curvature in the active

plane.

It will be noted that each system shown includes a positive cylindrical component at the front and a negative cylindrical component spaced therebehind followed by a field flattening member (element 6 in Figs. 1 and 2 and element 47 in Fig. 3) comprising a lens having negative power in the neutral plane and a net flattening effect on the inherently inward curving secondary field in the active plane.

WHAT WE CLAIM IS:—

1. An anamorphotic lens system for use with a spherical lens system so as to receive therefrom a convergent bundle of image forming rays and to form an anamorphosed image in a plane near the image plane of the spherical lens system, comprising two components, axially aligned with the spherical lens system, the front component, next to the spherical lens system, consisting of two simple cylindrical lenses and having a positive power in the active plane and substantially zero power in the neutral plane and the second component consisting of a positive cylindrical doublet and a simple biconcave cylindrical lens and having a negative power in the active plane numerically greater than the power of the front component and substantially zero power in the neutral plane, and a simple meniscus lens element having negative power in the neutral plane and located between the second component and the plane of the anamorphosed image with its concave surface facing the front of the lens system.

2. An anamorphotic lens system according to any of the preceding claims, wherein the negative meniscus lens element has spherical surfaces and differing negative powers in the active and the neutral planes and is disposed in front of a plano-convex cylindrical lens element having a positive power in the neutral plane of the system which is less than the negative power of the meniscus lens in the neutral plane.

3. Anamorphotic lens systems constructed substantially as hereinbefore described with reference to, and as shown in the accompanying drawings.

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873824 COMPLETE SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

Fig. 1.

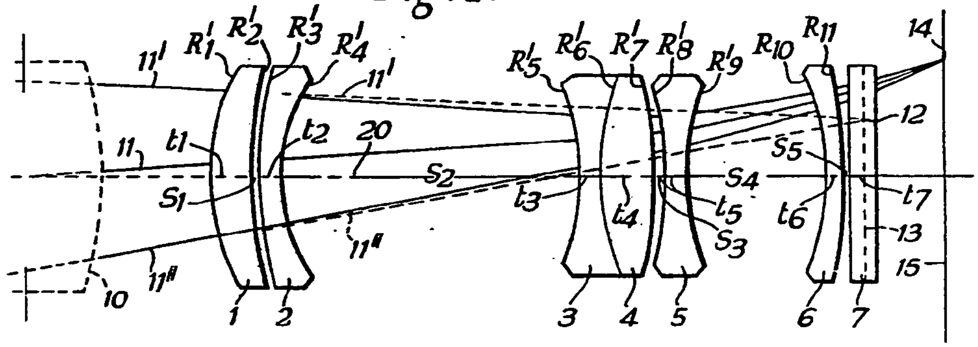

Fig. 2.

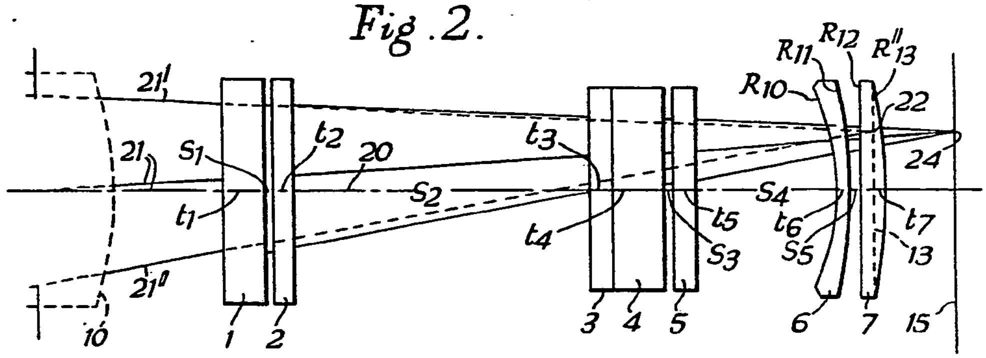

Fig. 3.